## 5.16.44 METHOD OF TESTING THE STRENGTH OF PORTLAND CEMENT CONCRETE USING THE MATURITY METHOD KT-44

### a. SCOPE

**a.1.** This method covers the procedure for using the maturity concept as a non-destructive method to determine in-place concrete strength. It may be used for determining the strength of concrete for opening to traffic or for removal of formwork.

**a.2.** This is a two step procedure. First, a relationship must be established between the measured maturity values and the concrete strength as measured by destructive methods (that is, through testing of beams or cylinders). The development of the maturity-strength curve may be done in a laboratory but is done preferably in the field at the beginning of construction using project materials and the project proportioning and mixing equipment. The second step is the instrumentation of the in-place concrete. Temperature probes are installed in the concrete and the temperature is measured. From those measurements, along with the age at which the measurements were taken, maturity values are determined. A maturity meter or temperature measuring device and a computer or calculator may be used to determine the maturity values.

### b. REFERENCED DOCUMENTS

**b.1.** KT 18; Air Content of Freshly Mixed Concrete by the Pressure Method

**b.2.** KT 21; Slump of Portland Cement Concrete

**b.3.** KT 22; Making and Curing Compression and Flexural Test Specimens in the Field

**b.4.** KT 23; Flexural Strength of Concrete (Third Point Loading Method)

**b.5.** AASHTO T 22; Compressive Strength of Cylindrical Concrete Specimens

**b.6.** ASTM C 1074; Standard Practice for Estimating Concrete Strength by the Maturity Method

### c. IMPLEMENTATION

**c.1.** When maturity testing is used, the Contractor and KDOT shall jointly develop a plan. The plan shall include:

- The Contractor shall be responsible for the development of the maturity curve. The curve development shall be monitored by KDOT.
- The temperature monitoring process of the constructed pavement or structure shall be the responsibility of the Contractor and monitored by KDOT.

**c.2.** For concrete furnished from a construction or stationary mixer, which is in place prior to construction of the specified project, a maturity curve may be established ahead of actual construction of the specified project. The test specimens shall be cast with concrete made from the same plant using the same mixture as will be used in the specified project. The engineer shall be informed and have an opportunity to observe the development of the maturity curve.

## d. THE MATURITY CONCEPT

**d.1.** The hydration of cement and gain in strength of the concrete are dependent on both curing time and temperature. Thus, the strength of the concrete may be expressed as some function of time and temperature. This information can then be used to determine the strength of concrete without conducting physical tests. The time-temperature function commonly used is the maturity concept proposed by Nurse-Saul (ASTM C1074).

$$M(^{o}C \times \text{hours}) = \Sigma[(T - T_o)\Delta t] \qquad (1)$$

**d.2.** Where M is the maturity in degree $^{o}$C–hours [M is also termed the time-temperature factor (TTF)], $\Delta t$ is the time interval in hours (or days), T is the average concrete temperature during the time interval $\Delta t$, and $T_o$ *is* the datum temperature at which concrete ceases to gain strength with time The value of $T_o = -10^{o}C$ ($14^{o}F$) is most commonly used. As a result, Eq.(1) becomes

$$M(^{o}C \times \text{hours}) = \Sigma[(T + 10)\Delta t] \qquad (2)$$

**Note a.** If there are large differences in temperature between the test specimens and the in-place concrete, an equivalent age function may be needed. See ASTM C 1074.

## e. APPARATUS

**e.1.** See KT 22 for specimen fabrication

**e.2.** Appropriate Testing Machine KT-23 or AASHTO T 22.

**e.3.** Maturity meter and sensors that automatically compute and display either temperature-time factor or equivalent age.

**e.4.** Hand-held thermometer with thermocouple wire and connectors.

## f. PROCEDURE

**f.1.** To establish a maturity-strength relationship for a concrete mix, a maturity meter or a thermal meter and a testing machine are needed, The following procedure shall be used: Note: Before using any maturity meter, check to be sure that the datum temperature is set to $-10\ ^{o}C$.

**f.1.a.** Cast and cure a minimum of twelve (12), 152 mm x 152 mm x 530 mm *(*6 in. x 6 in. x 21 in.) beams, or twelve (12), 52x30 more (6x12 in.) cylinders per KT-22. Test the air content and slump of the concrete per KT-18 and KT-21, and record these values. The concrete shall meet specifications. The beams shall be cast from a laboratory mix, or a field batch of at least 3 $m^3$ (3 cu. yd).

**f.1.b.** Embed a sensor or wire near the end of a test specimen to monitor the temperature. This specimen will be the last to be tested. A probe shall be inserted near one end at approximately the center of the specimen and such that it is approximately 75 mm (three in.) from the side and end. Secure the wire to prevent the wire from being inadvertently pulled out of the beam. When the thermal meter is used, the measured temperature should be substituted into Eq, (2) to obtain values of maturity. When a maturity meter is used, the meter computes the values. Twelve (12) test specimens shall be tested as described in **f.1.d.** below. An example calculation of the maturity factor is attached.

**f.1.c.** For field-cast specimens the meter can be stored in a lab trailer or vehicle with the probes run outside, to the beam in a sandpit. This will allow a maturity meter to be protected from the weather and theft.

**f.1.d.** Determine maturity values and strength at four different ages. Test three specimens for strength at each age and calculate the average strength at each age. The maturity value shall be calculated using the average temperature reading since the previous test for strength. The tests shall be spaced such that they are performed at somewhat consistent intervals of time and span the range of strength(s) required.

**f.1.d.1.** The first test (Test 1), normally would be performed at an age of approximately 12 hours when hot, summer temperatures prevail. During cooler conditions, the first test may be performed at the beginning of the day following casting of test specimens.

**f.1.d.2.** Additional test specimens may be cast at a later time and tested at earlier ages to add data to the strength-maturity relationship as an aid to determine the appropriate time to saw.

**f.1.d.3.** Plot the measured strength against the corresponding values of maturity at different ages, as determined by the maturity meter or by hand methods. The maturity number corresponding to the desired strength shall be used to determine when the concrete has reached the desired strength. An example of the Maturity-Strength Development Relationship is attached.

**f.2.** Since the influence of maturity on strength of concrete is somewhat different for various mixtures, a maturity-strength relationship established for one mixture shall not be used for another mixture.

**Note b.** To be considered the same mixture, no component may vary by more than five percent from the initial value

## g. VALIDATION

**g.1.** Once per month, a validation test shall be conducted to determine if concrete strength is being accurately represented by the current maturity curve. Cast and cure three (3) specimens using the same procedure and manner as used to develop the current maturity curve. Test all three as close as possible to the maturity value which was determined to represent the desired strength. If the average of these tests is within 0.34 MPa (±50 psi) for beams or 3.4 MPa ($\pm$ 500 psi) for cylinders of the original curve at the TTF, the original curve shall be considered validated. If the average value varies more than 0.34 MPa (50 psi) for beams or 3.4 MPa (500 psi) for cylinders from the original maturity curve value at the TTF at which the validation beams were tested, a new maturity curve shall be developed.

**Examples**

| Example of Maturity Calculation | | | | | Example of Maturity Data | |
|---|---|---|---|---|---|---|
| Age, Hrs | Temperature, degrees C | Avg Temp, degrees C | Avg Temp + 10, degrees C | TTF, C-Hrs | Maturity Number | Compressive Strength, MPa |
| 0 | 22 | | | | 358 | 6.97 |
| 1 | 22 | 22.0 | 32.0 | 32.0 | 407 | 9.66 |
| 2 | 25 | 23.5 | 33.5 | 65.5 | 460 | 12.28 |
| 3 | 27 | 26.0 | 36.0 | 101.5 | 511 | 13.31 |
| 4 | 29 | 28.0 | 38.0 | 139.5 | 568 | 14.76 |
| 5 | 33 | 31.0 | 41.0 | 180.5 | 613 | 17.1 |
| 6 | 36 | 34.5 | 44.5 | 225.0 | 667 | 17.79 |
| 7 | 37 | 36.5 | 46.5 | 271.5 | 718 | 18.28 |
| 8 | 37 | 37.0 | 47.0 | 318.5 | 772 | 19.66 |
| 9 | 36 | 36.5 | 46.5 | 365.0 | 960 | 22.07 |
| 10 | 35 | 35.5 | 45.5 | 410.5 | 998 | 23.31 |
| 11 | 32 | 33.5 | 43.5 | 454.0 | 1057 | 25.86 |
| 12 | 30 | 31.0 | 41.0 | 495.0 | 1183 | 26.62 |
| 13 | 29 | 29.5 | 39.5 | 534.5 | 1303 | 28.28 |